

# TENT COOPERATION TREATY

## PCT

### NOTIFICATION OF ELECTION

(PCT Rule 61.2)

From the INTERNATIONAL BUREAU

To:

Assistant Commissioner for Patents  
United States Patent and Trademark  
Office  
Box PCT  
Washington, D.C.20231  
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

<b>Date of mailing (day/month/year)</b> 04 July 2000 (04.07.00)	
<b>International application No.</b> PCT/IL99/00538	<b>Applicant's or agent's file reference</b> 119715.1 DB
<b>International filing date (day/month/year)</b> 13 October 1999 (13.10.99)	<b>Priority date (day/month/year)</b> 09 November 1998 (09.11.98)
<b>Applicant</b> MYR, David	

1. The designated Office is hereby notified of its election made:

☒ in the demand filed with the International Preliminary Examining Authority on:

23 May 2000 (23.05.00)

☐ in a notice effecting later election filed with the International Bureau on:

2. The election ☒ was

☐ was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

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**RCP**  
Established 1934

**Reinhold Cohn & Partners**  
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09/ 831 093  
03 MAY 2001

December 22, 2000

**FACSIMILE TRANSMISSION**  
**OF 17 PAGE(S)**  
**TO: 0049 89 2399 4465**

**EUROPEAN PATENT OFFICE**  
**D-80298 München**  
**GERMANY**

**Attention: Mr. S. Krischer**

Dear Mr. Krischer,

**Re: PCT Application No. PCT/IL99/00538**  
***"Method and System for Optimizing Transportation***  
***Route Design"***  
**MAKOR ISSUES & RIGHTS LTD.**  
**Our Ref: 119715.1 DB**

Responsive to the Written Opinion dated August 23, 2000 to which a response is due by the extended deadline of December 23, 2000, I enclose substitute pages 2, 2a, 15 and 22 to 28:

Although I shall attempt to relate to your objections point by point, allow me to remark that it appears that there has been a misunderstanding that needs to be resolved at the outset. You raise the repeated objection that the claims are inadequately supported by the description and that the description is not enabling. Allow me to point out that the actual computation preferably uses standard of-the-shelf linear programming packages that are well-known to design engineers and require no further description. Which particular package is used is likewise a matter of personal choice and requires no further elaboration.

Obviously, the use of known linear programming packages to solve linear programs is completely standard and hardly requires any detailed description. The problem to whose solution the present invention is directed is that the cost analysis function of earthworks excavation for transportation routes is not *linear* and so does not lend itself to direct solution using known linear programming packages.



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The applicants have overcome this problem by recognizing that the constraints that give rise to the above-mentioned non-linearity derive from absolute values in the cost function arising from the fact the excavation cost is always positive even when the earthworks must be excavated or filled in. Having recognized this, they then replace the absolute values in the cost function by variables as explained in particular on page 11 of the published application, so as to represent the cost function in linear form.

Once this is done, the remaining solution is carried out using known techniques which, as explained above, are well known in the art and require no further elaboration. You appear to anticipate that your objections of insufficiency might be unfounded since in paragraph 12.3 of the Written Opinion you allow for the possibility that the actual computation uses a commercially available computer-program. However, I cannot agree with your conclusion that "the **mere application** of a commercially available computer-program ... would **not involve an inventive step**, since this would only be the **intended use** of such technique or program." Obviously, the intended use of such a program is indeed to solve linear equations. But it is emphatically not the intended use of such programs to solve equations having non-linear constraints, and therefore such programs are clearly **not** intended for use in minimizing the cost function for earthwork excavation in a transportation route. The applicant has recognized that by manipulating the non-linear constraints, it is possible to render the cost function solvable by such programs notwithstanding that, **in the absence of such prior manipulation, the program could not be used to solve the optimization.**

I therefore respectfully submit that you are correct in realizing that the apparent absence of detailed description of an actual solution is because this is done using a commercially available computer-program; but that you are wrong to dismiss this as obvious because the invention provides a marked improvement of prior art optimization techniques, all of which are based on trial and error using interactive programs, exactly as described in D1.

In order to clarify this feature, I have amended the main method and system claims so as to recite that all non-linear constraints are replaced by equivalent linear constraints so as to render the height profile solving using standard linear programming tools. I realize that you probably would want to see this feature in the post-characterization clause of a claim drafted in two-part form as required by Rule 6.3(b) PCT and as requested in paragraph VII (4) of the Written Opinion. However, I prefer to defer this formal matter until the National Phase since it is not required in all jurisdictions. Likewise, I have deferred attending to your requirement to provide reference signs.

I have also added new Claims 4 and 17, which recite in detail those non-linear constraints that are replaced by equivalent linear constraints and the manner in which the non-linear cost function is thereby rendered linear.

I apologize for the redundancy of Claims 3 and 4 and of Claims 17 and 18, all of which have been deleted.

On pages 2 and 2a, I have added some discussion of document **D1** in accordance with Rule 5.1(a)(ii) PCT.

With regard to your objection of clarity in Claim 1 as explained in paragraph 8 of the Written Opinion, I have attempted to clarify the claim without adding new matter. Similar amendments have been effected to the independent system claim 14. I believe that in view of the above explanations and the fact that there is indeed no need to provide an algorithm, the claim is now clear.

Moreover, a point-by-point discussion now follows:

- 8.1 "design criteria" may be seen from the formulation of constraints (page 9, line 13):

"c) Constraints of allowable grades (separately for control points near to intersection (e.g. 50m) and for other control points.)

"d) Constraints of intersections (elevations of intersection points of different roads must be same)."

More "design criterion" may be seen from Refinements (page 18) "... recommended to add as a further constraint that the difference between adjacent road grades should not exceed predefined value per certain distance (e.g. 0.5% per 10m)." This constraint will supply smoothness of road. Another "design criterion" is the "Fixed points" mentioned on page 18, lines 25-28.

- 8.2 Concerning "route profile" it is explained on page 21, lines 1 and 2 that route profile data shows land heights at sample points along each of said at least one transportation route." It thus emerges that the profile is three-dimensional, contains height values and defines land before constructing the route.

- 8.3 "per-unit cost estimates" may be seen from explanation (page 6, line 25): "Let price of fill =  $f_0$  (money unit/ volume unit)". For retaining walls is implied (money unit/ area unit) as may be seen from Equation (1) on page 6, where measure of  $G$  is meter.

- 8.4 In the application three approaches are presented to "computing a height profile". All of them (one linear and two non-linear) are finally formulated as standard linear programming tasks: linear objective function and linear constraints. There are several methods for solving this task. But as noted above, applicants did not invent any of them. All these methods are now available as software packages. For the record, the Applicants have tried two: Vanguard Dpro 2.1 and CPLEX 6.5. Results were very satisfactory in reasonable time.

In once case, the objective function is non-linear representing the total cost of earthwork (fill, cut, retaining walls, moving soil out or in project area) (page 6, equation (1)). In another case, the non-linear objective function is the total sum of unsigned differences between proposed and existing elevations (page 16, equation (14)). Finally, an initially linear objective function includes unsigned difference between total cut and fill volumes that is minimized (page 13, Equation (8)).

In all three approaches constraints are designed "to meet design criteria" and/or supply linearity of objective function.

With regard to your objection in paragraph 10.1, "boundary grid points" are defined on page 4, lines 15-18 where it is stated that: "BGP are grid points located on edges of roads, i.e. points for which distance to the road centerline is equal to half of the road width (with some tolerance). BGP are used for cost estimation of retaining walls."

Likewise, "control points" are defined on page 5, lines 3 to 5 wherein it is stated that "X and Y coordinates of control points and grid points are entered as input data and coordinates Z are an output of the optimization procedure."

You ask in 10.1 how the elevation values are computed and I have related to this in answer to 8.4 above. It may further be noted that for small projects having fewer than 200 CPs, GPs and BGPs, the solution can be computed even using Microsoft® Excel. For medium or large projects (thousands of CPs, GPs and BGPs) Excel Microsoft® and other low capacity optimization tools are unsuitable due to restricted memory and performance speed possibilities of such software tools.

As to how they are used, after the nonlinear and linear problems are formulated as strictly standard linear programming tasks, defining a rectangular matrix of numbers expressing coefficients of linear objective function and also linear constraints all that remains is to follow the User's Guide recommendations of any commercially available Linear Programming package as are widely available. See, for example, "*Optimization Software Guide*", Jorge J. More, Stephen J. Wright, Philadelphia 1993.

You then ask how the optimization problem is formulated as a nonlinear and as a linear task. The answer to this question has three parts owing to three different approaches.

Grid optimization approach (page 4, line 6) is formulated initially as a nonlinear task due to objective function (page 6, Equation (1)) includes members with absolute value of variables  $Z_q$  (pages 7-8, Equations (2)-(5)). Note, however, that all constraints (pages 8-10, constraints a)-e)) are linear, namely:

- (a) The relation between relative elevations of CPs A, B and relative elevation of GP Q (page 8, lines 15-23) is linear. By "relative

elevations" is meant differences between proposed and existing elevations (page 6, lines 4,5). From this constraint is derived interpolation of CPs via GPs (page 9, lines 4-8).

- (b) These constraints present equality of linear expressions of CPs elevations for adjacent intervals between neighbor CPs via GPs elevations (page 9, lines 4-12). More detailed: CP's elevations that were interpolated twice (use constraint a)) - for two adjacent intervals from two sides: from back and from forward must be equal.
- (c) These constraints are seem to be nonlinear due to absolute value of expression that includes variables: Z and Z', but in fact it is brief form for pair of absolutely linear constraints:  
$$(H' + Z' - (H+Z))/D < S$$
$$(H' + Z' - (H+Z))/D > -S$$
- (d) Constraints of intersections evidently are linear.
- (e) Constraints for lack or excess total fill or excavation volumes are linear. These constraints are designed to remove the absolute value in the last part of the objective function (page 8, Equation (5)). With this constraint this last part becomes linear (page 10, lines 10-14).

It remains only to consider the non-linearity of objective function. This is discussed on page 10, line 15 until page 11, line 24. In particular, please note the example of replacing nonlinear expression on page 11, line 14 by its linear equivalent form (page 11, Equation (7)). Also note the explanation on page 11, lines 20-24.

This approach is the most complicated of all three and discussion of the remaining two approaches will add nothing essential to distinguish from considered approach.

Further in 10.1 you aver that the statement in original claims 7 and 21 (corresponding to new claims 6 and 19) "allowing a surface ...between adjacent control points to have a higher gradient" is a contradiction to the definition of control points in Claim 2. However, Claims 6 and 19 first recite "...including the step of adding control points" and only after that step is there provided "...allowing a surface ...between adjacent control points to have a higher gradient". So there is in fact no contradiction.

The manner in which earthworks are taken into account may relate to the optional subdivision of lots. Claim 5(e) recites the step of "iteratively shifting said model vertically in order to minimize total cost". Here earthworks are formed from components represented in the grid approach objective function: i.e. fill and cut volumes, retaining walls areas and moving soil out or in project area.

However, this shifting would be applied only for large projects, when full grid optimization approach (including lots) consumes too much computer time and/or memory.

Coming now to paragraph 11, I would comment as follows. Your objection in 11.1 is strange seeing that the order of performing the method steps of Claim 1 (by way of example) is very clearly not constrained by the order in which the method steps are recited. Therefore, the statement that "[I]n the method claims that follow, alphabetic characters used to designate claim steps are provided for convenience only and do not imply any particular order of performing the steps" appears completely justified. I would agree with your objection if the order in which the method steps must be carried out is invariant: but this is not the case.

Your objection in 11.2 is certainly true: the caption "Equation (11)" should relate to the first uncaptioned equation on the page and a substitute sheet is enclosed.

Allow me further to emphasize that the issues you raise in a paragraph 12.2, namely that the constraints are not linear owing to the "abs", it is precisely that this non-linearity is replaced by a linear function that enables the subsequent use of standard programming techniques and packages.

Moreover, it is true that "max" and "min" are non-linear function, but in this case their arguments are not variables. These arguments are expressions including constants from input data as explained on page 15, lines 8, 10-11.

In all three approaches variables are relative elevations, i.e. differences between proposal and existing elevations. However, for two centerline optimizations these differences are measured only for control points (that is only on centerlines), for grid optimization these differences are measured for all grid points.

For the "grid optimization approach", the objective function is the total cost of earthwork (page 6, lines 6-20).

For linear programming approach objective function is the cumulative difference between fill and cut volumes for centerlines only (page 12, lines 14-17) and as shown in Fig. 3.

For "centerline optimization - nonlinear programming approach" the objective function is defined on page 16, lines 17-19.

For "grid optimization approach" the constraints are as explained above. For the linear approach, the constraints are presented on page 15. Here constraints represent equality of elevations of control points on different centerlines at their intersection; and represent the constraint on grades that could not exceed allowable grades described by "design criteria".

Present intrinsic constraints imply that all proposed elevations are enclosed between maximum and minimum values that depend on allowable grades and planar distances between every pair of control points. All three

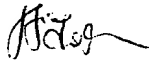
approaches should also include smoothing constraints mentioned in Refinements (page 17, lines 27-28, page 18, lines 1-2).

Finally, since all nonlinear matter is reduced to strictly linear functions, the problem of local minima to which you refer does not arise.

I have tried to relate to all your objections apart from those formal matters that I have indicated will be deferred until the National Phase. However, if notwithstanding my detailed explanations, you still believe that further amendment is required, I would very much appreciate discussing the case with you before you issue an unfavorable IPER.

Allow me to take this opportunity to wish you all the best for Christmas and the New Year.

Yours sincerely,



Jonathan J. Topper

JJT(00016\_FAX)  
Confirmation by airmail



\* \* \* 22.DEC.2000 11:29 \* \*

TTI REINHOLD COHEN &amp; PARTNERS

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S : רגיל  
M : זיכרון

D : מפורט  
P : משיכה

F : משופר  
L : שידור מושהה

E : תיקון שיבושים (ECM)  
# : איחוד

## PATENT COOPERATION TREATY



PCT

REC'D 20 FEB 2001

## INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

14

Applicant's or agent's file reference 119715.1 DB		<b>FOR FURTHER ACTION</b> See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/IL99/00538	International filing date (day/month/year) 13/10/1999	Priority date (day/month/year) 09/11/1998
International Patent Classification (IPC) or national classification and IPC G06F17/60		
Applicant MAKOR ISSUES AND RIGHTS LTD. et al.		
<p>1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.</p> <p>2. This REPORT consists of a total of 10 sheets, including this cover sheet.</p> <p><input checked="" type="checkbox"/> This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).</p> <p>These annexes consist of a total of 10 sheets.</p>		
<p>3. This report contains indications relating to the following items:</p> <ul style="list-style-type: none"><li>I <input checked="" type="checkbox"/> Basis of the report</li><li>II <input type="checkbox"/> Priority</li><li>III <input checked="" type="checkbox"/> Non-establishment of opinion with regard to novelty, inventive step and industrial applicability</li><li>IV <input type="checkbox"/> Lack of unity of invention</li><li>V <input type="checkbox"/> Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement</li><li>VI <input type="checkbox"/> Certain documents cited</li><li>VII <input checked="" type="checkbox"/> Certain defects in the international application</li><li>VIII <input checked="" type="checkbox"/> Certain observations on the international application</li></ul>		
Date of submission of the demand  23/05/2000		Date of completion of this report  16.02.2001
Name and mailing address of the international preliminary examining authority:   European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465		Authorized officer  Krischer, S  Telephone No. +49 89 2399 7484  

# INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/IL99/00538

## I. Basis of the report

1. This report has been drawn on the basis of *(substitute sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments (Rules 70.16 and 70.17).):*

### Description, pages:

1,3-14,16-21 as originally filed

2,2a,15 as received on 09/01/2001 with letter of 09/01/2001

### Claims, No.:

1-27 as received on 09/01/2001 with letter of 09/01/2001

### Drawings, sheets:

1-5 as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language: , which is:

- ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
- ☐ the language of publication of the international application (under Rule 48.3(b)).
- ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- ☐ contained in the international application in written form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

# INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/IL99/00538

- ☐ the description, pages:
- ☐ the claims, Nos.:
- ☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

*(Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)*

6. Additional observations, if necessary:

### III. Non-establishment of opinion with regard to novelty, inventive step and industrial applicability

1. The questions whether the claimed invention appears to be novel, to involve an inventive step (to be non-obvious), or to be industrially applicable have not been examined in respect of:

- ☒ the entire international application.
- ☐ claims Nos. .

because:

- ☐ the said international application, or the said claims Nos. relate to the following subject matter which does not require an international preliminary examination (*specify*):
- ☒ the description, claims or drawings (*indicate particular elements below*) or said claims Nos. 1-27 are so unclear that no meaningful opinion could be formed (*specify*):  
**see separate sheet**
- ☒ the claims, or said claims Nos. 1-27 are so inadequately supported by the description that no meaningful opinion could be formed.
- ☐ no international search report has been established for the said claims Nos. .

2. A meaningful international preliminary examination report cannot be carried out due to the failure of the nucleotide and/or amino acid sequence listing to comply with the standard provided for in Annex C of the Administrative Instructions:

- ☐ the written form has not been furnished or does not comply with the standard.
- ☐ the computer readable form has not been furnished or does not comply with the standard.

### VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:

**INTERNATIONAL PRELIMINARY  
EXAMINATION REPORT**

International application No. PCT/IL99/00538

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**s e separat sheet**

**VIII. Certain observations on the international application**

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

**s e separate sheet**

**Re Item III**

**Non-establishment of opinion with regard to novelty, inventive step and industrial applicability for claims 1-5**

- 1 For independent claims 1 and 14, the reasons are set out in section VIII.
- 2 Since the dependent claims refer to invalid independent claims, no opinion can be established either.

**Re Item VII**

**Certain defects in the international application**

- 3 Reference is made to the following **document**:  
  
D1 Allen, L. G.; Poidevin, M. G. "Cost Effective Design - The Use of Computer Aided Drafting In: Route Selection, Earthworks Optimisation and Rail Track Engineering", Conference on Railway Engineering, Perth/Australia September 1987; XP-000917757
- 4 Independent claims 1 and 15 are not in the **two-part form** in accordance with Rule 6.3(b) PCT, which in the present case would be appropriate, with those features known in combination from the prior art (document D1) being placed in the preamble (Rule 6.3(b)(i) PCT) and with the remaining features being included in the characterising part (Rule 6.3(b)(ii) PCT).
- 5 The features of all claims are not provided with **reference signs** placed in parentheses (Rule 6.2(b) PCT).

**Re Item VIII**

**Certain observations on the international application**

- 6 The application does not meet the requirements of Article 6 PCT, because independent claims 1 and 15 are **not clear**.

7 **Clarity of claim 1**

- 7.1 The claim attempts to define the subject-matter in terms of the **result to be achieved** which merely amounts to a statement of the underlying problem: the **step (d) of "computing a height profile ... by replacing all non-linear constraints by equivalent linear constraints"** (line 13) is the **kernel** of the claimed "computer-implemented method for designing transportation routes" (line 2) since it is the only design step in the method ((a), (b) and (c) are input steps). The claim does not define **how** this computation and replacement step should be executed. The technical features necessary for achieving this result are missing. No **algorithm** for this computation is given. No indication is given in the claim of how to perform the **generally impossible step of changing non-linearity into linearity**. Therefore, it is unclear how perform the main step of the method. It is especially unclear how the additional conditions of "meeting said constraints" (line 14) should be reached.
- 7.2 It is unclear **how standard linear programming tools should be used** (line 15) **without knowing a linear objective function** which is necessary for these tools.
- 7.3 It is not clear **why** in step (d) all non-linear constraints should be "**replaced by equivalent linear constraints**" (line 13) whereas the only kind of constraints used in the method of claim 1 is **already linear** ("linear constraints of allowable grades", line 4).

8 **Clarity of independent claim 14**

- 8.1 The clarity objections of method claim 1 apply accordingly to system claim 14.

9 **Clarity of dependent claims**

- 9.1 The following expressions in **claims 2, 15** is unclear: "**calculating a ... elevation ... using linear or nonlinear programming**" (**step iii**): This is also a definition of the subject-matter in terms of the **result to be achieved** which merely amounts to a statement of the underlying problem as in claim 1. The following **questions** arise that should be **answered by the claims**: How are the elevation

values computed? There are so many linear and nonlinear programming solution techniques: Which one can be used? Which one cannot be used? How are they used? How is the optimization problem formulated as a nonlinear and as a linear programming task? What are the variables to minimize? What is the objective function? What are the constraints? How is the problem of local minima in case of the nonlinear programming treated?

## 10 Clarity of the description

- 10.1 The passage on page 21, lines 15-18 implies that it would be possible to perform step (d) of claim 1 ("computing the height profile") before getting the input for these computations in steps (a)-(c).

Therefore, the constraints about necessarily executing some steps of claim 1 **in a special order** should have been **explicitly stated in the description** or in the claims, e.g. by **adding the word "then"** after "and" at the end of step (c) in claim 1.

## 11 Sufficient disclosure

- 11.1 **The description does not satisfy Article 5 PCT, i.e. that the invention is *not disclosed in sufficient detail* for a person skilled in the art to reproduce it.**
- 11.2 The description does **not disclose** how to perform **the most important step** of the method and system for designing transportation routes, which is the step of ***computing a height profile by replacing all non-linear constraints by equivalent linear constraints and by using standard linear programming tools*** such that **land-cut and land-fill costs are minimized**.

It is **impossible** for a skilled person to use the claimed method, to construct the claimed system, or to program the claimed computer program without being taught **how the core** of the method/system/program **works**.

The description only gives **three vague formulations of the optimization problem** as two nonlinear and one linear programming tasks, **without disclosing a solution technique** for any of these problem formulations. The **deficiencies** of



the problem formulations are the following:

- (1) **first nonlinear programming problem formulation**, called "**grid optimization**" (pages 4-12): The description does **not teach nonlinear** programming techniques to treat the nonlinear problem formulation, but **uses standard linear programming tools** in treating the nonlinear problem formulation (page 11, line 1: "allowing solution by means of linear programming"). However, it fails in disclosing in sufficient detail the transformation of the nonlinear problem formulation into a linear one (see section below).
- (2) **"linear" programming problem formulation**, called "**centerline optimization - linear programming approach**" (pages 12-16): Although the description states that this problem formulation is linear, it seems that it is **not linear** since the **constraints are not linear**. For example the constraints b) and c) (page 15) contain the nonlinear functions "abs", "max" and "min" which cannot be represented by matrices. If the arguments of these functions should be **only constants**, then the expressions containing these function would **not be constraints** for the linear problem formulation. Furthermore, in the case it was a linear programming problem formulation, the description would not teach **which one of the various linear solution techniques would be adapted** to the problem (e.g. which one of the families of **simplex methods** or of **interior-point methods**).
- (3) **second nonlinear programming problem formulation**, called "**centerline optimization - nonlinear programming approach**" (pages 16-18): The same objections as for the first nonlinear programming problem formulation hold.

### 11.3 Transformation: nonlinear to linear

The **only passage** in the description which is dealing with the transformation of the nonlinear programming problem formulation into a linear programming problem formulation (pages 10, line 18 until page 12, line 5) does **not sufficiently disclose** how to do this transformation:

The main problem is that it is not disclosed **what is to be substituted by what**:

Page 11, line 3 says that " $Z_q - a_i, \dots$  is replaced by  $\dots Z_q - a_i = Uqai_1 - Uqai_2$ ". This

means that the absolute function in the expression " $|Z_q - a_i|$ " would be maintained after substitution: " $|Uqai_1 - Uqai_2|$ ".

Page 11, line 14 says that " $|Z_q - a_i|$ " is replaced by " $Uqai_1 + Uqai_2$ ". This means that the whole expression " $|Z_q - a_i|$ " including the absolute function signs " $| \cdot |$ " is replaced, in contradiction with the preceding statement. Furthermore, the **operator "+"** in " $Uqai_1 + Uqai_2$ " **contradicts** the lines 5-13 where only the **operator "-"** is used in the replacing expressions (e.g.  $Uqai_1 - Uqai_2$ ).

Page 11, lines 18 and 19 show the transformation of the defining expression of the **cost function " $C_q(Z_q)$ "**. This example is **neither deducible from the first** one of the contradicting substitution rules, **nor from the second** one. Herein, the whole expression " $|Z_q - a_j| + a_j$ " is replaced by " $Uqaj_1 + Uqaj_2$ ". This is the third way of substitution.

Furthermore, there are **contradicting statements** about **what the new variables** are: the formulation "pair of new variables" (page 11, line 3; page 12, lines 1, 3) indicates that for example " **$Uqai_1$** " **designates one variable** and " $Uqai_2$ " the other variable of the pair.

On the other hand, the statement that "all  $a_j, b_j, P_j, \dots$  are constants and their sums and products have no influence on the optimization" (page 11, line 22) indicates that " **$Uqai_1$** " **designates the product of the variables "U", "q", "a" and "i"**.

The transformation should concern **both the nonlinear objective function** (Equation (1), page 6, line 8) and the **nonlinear constraint** (page 10, line 5: "constraint e) for lack or excess of total fill" is nonlinear since its definition on line 6 contains the boolean operator "or"; this means that a case analysis has to be done as in line 14 which is not possible in the linear framework). But in the constraint e), the expressions to be substituted of type " $Z_q - a_i$ " as stated on page 11, lines 3-13 do **not appear**. Therefore, even if it would be clear how to use the transformation, it **could not be applied to constraint e)**.

11.4 The following **questions** arise when a skilled person tries to implement the invention:

- How are the **various optimization steps** in Figure 1 executed (boxes "optimization process", "optimization of transportation", "optimal points of intersection", "optimal vertical alignment of roads and lots", "optimal cross sections", "optimal quantity output", "minimum cost output", "optimal transportation output")? What is the relation between these optimization steps and the three optimization problem formulations on pages 4-18?
- How do the earthworks for subdivision lots (page 19) influence the optimization algorithms? What are the measurable parameters of these lots that are necessary for the computation?
- As to Equation (1) (page 6): What is the meaning of " $N$ "? Which points  $Q$  are used? Grid points, boundary grid points, control points, any other points?

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Such equalization is an iterative process requiring repeated fine-tuning by the engineer. The iteration may be repeated numerous times before the road system satisfies all of the physical constraints and the cut and fill quantities are properly balanced. Conventionally, the design has been a trial and error affair according to the experience of the civil engineer. The vertical alignment is determined for one road at a time and not for the entire road system. Earthworks of subdivision lots which border transportation routes have also not conventionally been taken into account, nor has the economical factor been properly considered.

A CAD approach to the design of rail tracks is presented by L.G. Allen *et al.* in "*Cost Effective Design – The Use of Computer Aided Drafting In: Route Selection, Earthworks Optimisation and Rail Track Engineering*" appearing in Conference on Railway Engineering, Perth/Australia, September 1987; XP-000917757. However, this article makes no reference to minimization of earthworks cost. Rather it attempts to achieve cost-effective design using an interactive CAD process. Thus, cost effectiveness is the result of user's interactive work (i.e. trial and error) and is not an automatic computerized process that uses pre-prepared data allowing the route to be optimized without any user interaction. In this respect, the CAD tools disclosed by this article are typical of prior art methods that relate on trial and error for optimizing transportation routes.

## SUMMARY OF THE INVENTION

A principal the object of the invention is thus to develop a method of road design that results in lower construction cost.

A further object of the invention is to facilitate comparison of different layouts and different unit prices so as to obtain better cost-effectiveness during the preliminary planning stage.

- 2a -

According to a broad aspect of the invention there is provided a computer-implemented method for designing transportation routes, the method comprising the steps of:

- (a) supplying linear constraints of allowable grades to be met in respect of at least one of said transportation routes,
- (b) obtaining route profile 3-D coordinates showing land heights at sampled points along each of said at least one transportation route prior to construction thereof,
- (c) supplying cost estimates per working unit in respect of land-cut and land-fill operations, and
- (d) computing a height profile of said at least one transportation route which meets said constraints and for which said land-cut and land-fill operations are adjusted to give a minimum cost by replacing all non-linear constraints by equivalent linear constraints so as to render the height profile solving using standard linear programming tools.

Such a method establishes a direct relationship between prevailing economic conditions and the status of the transportation system as a technical

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$$\sum_{j=1}^{j=K} \sum_{i=1}^{i=N_j} (D_{(i-1),j} + D_{ij}) \cdot (Z_{ij} + 10,000) - \sum_{j=1}^{j=K} \sum_{i=1}^{i=N_j} (D_{(i-1),j} + D_{ij}) \cdot 10,000 < 0 \text{ or } > 0$$

Equation (11)

**Constraints:**

(a) Elevations of intersection points of different roads having respective indices  $j_1$  and  $j_2$  must be same, i.e.:

$$Z_{1j_1} + H_{1j_1} - Z_{1j_2} - H_{1j_2} = 0,$$

Where:

1<sup>st</sup> point of  $j_1$ <sup>th</sup> road coincides with 1<sup>st</sup> point of  $j_2$ <sup>th</sup> road;

$Z_{1j_1}$  and  $Z_{1j_2}$  are relative elevations at these points;

$H_{1j_1}$  and  $H_{1j_2}$  are existing elevations at these points.

(b) The absolute value of the gradient between adjacent control points ( $i$ ,  $j$ ) having respective elevations  $H_{ij}$  and  $H_{(i+1)j}$  cannot exceed a predetermined allowable maximum value,  $G_{max}$ :

$$|Z_{ij} + H_{ij} - Z_{(i+1)j} - H_{(i+1)j}| / D_{ij} < G_{max},$$

for  $j = 1, \dots, K$ ;  $i = 1, \dots, N_j$ .

(c) Elevation at each CP should belong to maximal possible allowable interval:

$$Z_{i_0, j_0} < 10,000 + \max \left\{ 0, 0.5 \cdot \left\{ \max_{i=1}^{i=K} \max_{j=1}^{j=N_j} (H_{i,j} - H_{i_0, j_0} - D_{i_0, j_0, i, j} \cdot G_{max}) \right\} \right\}$$

Equation (12)

and

$$Z_{i_0, j_0} > 10,000 - \min \left\{ 0, 0.5 \cdot \left\{ \min_{i=1}^{i=K} \min_{j=1}^{j=N_j} (H_{i,j} - H_{i_0, j_0} + D_{i_0, j_0, i, j} \cdot G_{max}) \right\} \right\}$$

Equation (13)

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**CLAIMS:**

1. A computer-implemented method for designing transportation routes, the method comprising the steps of:

- 5 (a) supplying linear constraints of allowable grades to be met in respect of at least one of said transportation routes,
- (b) obtaining route profile 3-D coordinates showing land heights at sampled points along each of said at least one transportation route prior to construction thereof,
- 10 (c) supplying cost estimates per working unit in respect of land-cut and land-fill operations, and
- (d) computing a height profile of said at least one transportation route which meets said constraints and for which said land-cut and land-fill operations are adjusted to give a minimum cost by replacing all non-linear constraints by equivalent linear constraints so as to  
15 render the height profile solving using standard linear programming tools.

2. The method according to Claim 1, wherein step (d) includes:

- 20 i) representing a surface of the at least one transportation route as a 3-dimensional model having grid points and boundary grid points being grid points located on edges of roads for which distance to the road centerline is substantially equal to half of the road width,
- ii) defining control points such that a gradient of the road surface is constant between adjacent control points by entering X and Y coordinates of said control points as input data, and
- 25 iii) calculating a respective elevation of each point on the road surface between adjacent control points as well as a respective elevation of each control point using linear or non-linear programming.

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3. The method according to Claim 1 or 2, wherein the route profile data includes soil composition and per unit excavation cost for each different level having a discrete soil composition.

4. The method according to any one of the preceding claims, wherein:

5 the height profile is computed to minimize a total cost of the earthworks represented by the following objective function:

$$\sum_{q=1}^{q=N} (F_q(Z_q) \cdot G + W_q(Z_q) + C_q(Z_q) \cdot G + V_q(Z_q)) \cdot G + D$$

where:

G is grid size;

10  $F_q(Z_q)$  is cost of fill at point Q, where the proposed GP elevation is higher than the existing GP elevation ( $Z_q > 0$ );

$W_q(Z_q)$  is cost of retaining wall for fill at point Q, where proposal GP is above existing GP ( $Z_q > 0$ );

15  $C_q(Z_q)$  is cost of excavation at point Q, where the proposed GP is lower than the existing GP ( $Z_q < 0$ );

$V_q(Z_q)$  is cost of retaining wall for excavation at point Q, where proposed GP is below existing GP ( $Z_q < 0$ );

D is cost of total difference between fill and excavation volumes moving in or out of entire roads system area.

20  $Z_q = Z'_q - Z_e$ , where  $Z'_q$  is the proposed elevation and  $Z_e$  is the elevation at point Q,

the cost  $C_q(Z_q)$  is represented as the solution of a non-linear equation represented by:

$$C_q(Z_q) = 0.5 \cdot \left( \sum_{j=1}^{j=Kq} (|Z_q - aj_q| + aj_q - |Z_q - bj_q| - bj_q) \cdot Pj_q + \{ |Z_q - bK_q| - (Z_q - bK_q) \} \cdot P_q \max \right)$$

and



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each of the absolute expressions  $Z_q - a_i$ ,  $Z_q - b_i$ ,  $Z_q - c_j$ ,  $Z_q - d_j$ ,  $Z_q - e_j$ ,  $Z_q - f_j$  is replaced by a pair of new variables, as follows:

$$(*) Z_q - a_i = Uqai_1 - Uqai_2, i=1, \dots, K_q,$$

$$(*) Z_q - b_i = Uqbi_1 - Uqbi_2, i=1, \dots, K_q,$$

$$5 \quad (*) Z_q - b_{K_q} = UqbK_1 - UqbK_2;$$

$$(*) Z_q - c_j = Uqcj_1 - Uqcj_2, j=1, \dots, L,$$

$$(*) Z_q - d_j = Uqdj_1 - Uqdj_2, j=1, \dots, L,$$

$$(*) Z_q - d_L = UqdL_1 - UqdL_2;$$

$$(*) Z_q - e_j = Uqej_1 - Uqej_2, j=1, \dots, M,$$

$$10 \quad (*) Z_q - f_j = Uqfj_1 - Uqfj_2, j=1, \dots, M,$$

$$(*) Z_q - f_M = UqfM_1 - UqfM_2.$$

so as to render all of the constraints linear and amenable to computation using Linear Programming techniques.

5. The method according to Claim 2 or 3, further including:

- 15 (e) iteratively shifting said model vertically in order to minimize total cost whilst taking into account the cross-section of each transportation route, so as to derive a set of control points having elevations that define vertical alignment of the transportation routes.

- 20 6. The method according to Claim 5, further including the step of adding control points and allowing a surface of the transportation route between adjacent control points to have a higher gradient.

7. The method according to Claim 5 or 6, wherein accuracy is improved by reducing a mutual separation between adjacent grid points.

- 25 8. The method according to any one of Claims 5 to 7, wherein accuracy is improved by providing a higher resolution digital terrain model.

9. The method according to any one of the Claims 2 to 8, wherein at least one of the transportation routes includes one or more subdivision lots adjoining a boundary of the transportation route and in step (d)(i) there are  
30 added to the model respective sections and boundaries of said subdivision lots

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so as to take into account earthworks required to conform an elevation of the transportation route to corresponding elevations of the subdivision lots.

10. The method according to any one of the preceding claims, wherein the transportation routes include at least one road.

5 11. The method according to any one of the preceding claims, wherein the transportation routes include at least one rail track.

12. The method according to any one of the preceding claims, wherein the transportation routes include at least one pedestrian path.

13. The method according to any one of the preceding claims applied to a plurality of transportation routes comprising an integrated project so as  
10 optimize excavation costs for the project.

14. A computer-implemented system for designing transportation routes, said system comprising a computer coupled to a memory and a data output device,

15 (a) there being stored in the memory transportation route data including:

i) linear constraints of allowable grades to be met in respect of at least one of said transportation routes,

20 ii) route profile 3-D coordinates showing land heights at sampled points along each of said at least one transportation route prior to construction thereof, and

iii) cost estimates per working unit in respect of land-cut and land-fill operations; and

25 (b) the computer being responsive to the linear constraints, the route profile 3-D coordinates and the cost estimates per working unit for computing a height profile of said at least one transportation route which meets said design criteria and for which said land-cut and land-fill operations are adjusted to give a minimum cost by replacing all non-linear constraints by equivalent linear constraints

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so as to render the height profile solving using standard linear programming tools.

15. The system according to Claim 14, wherein the computer is programmed to:

- 5 i) represent a surface of the at least one transportation route as a 3-dimensional model having grid points and boundary grid points being grid points located on edges of roads for which distance to the road centerline is substantially equal to half of the road width,
- 10 ii) define control points such that a gradient of the road surface is constant between adjacent control points by entering X and Y coordinates of said control points as input data, and
- iii) calculate a respective elevation of each point on the road surface between adjacent control points as well as a respective elevation of each control point using linear or non-linear programming.

15 16. The system according to any one of Claims 15, wherein the route profile data includes soil composition and per unit excavation cost for each different level having a discrete soil composition.

17. The system according to any one of Claims 14 to 16, wherein  
20 wherein the computer is programmed to compute the height profile by minimizing a total cost of the earthworks represented by the following objective function:

$$\sum_{q=1}^{q=N} (F_q(Z_q) \cdot G + W_q(Z_q) + C_q(Z_q) \cdot G + V_q(Z_q)) \cdot G + D$$

where:

G is grid size;

25  $F_q(Z_q)$  is cost of fill at point Q, where the proposed GP elevation is higher than the existing GP elevation ( $Z_q > 0$ );

$W_q(Z_q)$  is cost of retaining wall for fill at point Q, where proposal GP is above existing GP ( $Z_q > 0$ );

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$C_q(Z_q)$  is cost of excavation at point Q, where the proposed GP is lower than the existing GP ( $Z_q < 0$ );

$V_q(Z_q)$  is cost of retaining wall for excavation at point Q, where proposed GP is below existing GP ( $Z_q < 0$ );

5 D is cost of total difference between fill and excavation volumes moving in or out of entire roads system area.

$Z_q = Z'_q - Z_e$ , where  $Z'_q$  is the proposed elevation and  $Z_e$  is the elevation at point Q,

the cost  $C_q(Z_q)$  is represented as the solution of a non-linear equation  
10 represented by:

$$C_q(Z_q) = 0.5 \cdot \left( \sum_{j=1}^{j=K_q} (|Z_q - a_{j_q}| + a_{j_q} - |Z_q - b_{j_q}| - b_{j_q}) \cdot P_{j_q} + \{ |Z_q - b_{K_q}| - (Z_q - b_{K_q}) \} \cdot P_q \max \right)$$

and

each of the absolute expressions  $Z_q - a_i$ ,  $Z_q - b_i$ ,  $Z_q - c_j$ ,  $Z_q - d_j$ ,  $Z_q - e_j$ ,  $Z_q - f_j$  is replaced by a pair of new variables, as follows:

- (\*)  $Z_q - a_i = U_{qai_1} - U_{qai_2}$ ,  $i=1, \dots, K_q$ ,
- 15 (\*)  $Z_q - b_i = U_{qbi_1} - U_{qbi_2}$ ,  $i=1, \dots, K_q$ ,
- (\*)  $Z_q - b_{K_q} = U_{qbK_1} - U_{qbK_2}$ ;
- (\*)  $Z_q - c_j = U_{qcj_1} - U_{qcj_2}$ ,  $j=1, \dots, L$ ,
- (\*)  $Z_q - d_j = U_{qdj_1} - U_{qdj_2}$ ,  $j=1, \dots, L$ ,
- (\*)  $Z_q - d_L = U_{qdL_1} - U_{qdL_2}$ ;
- 20 (\*)  $Z_q - e_j = U_{qej_1} - U_{qej_2}$ ,  $j=1, \dots, M$ ,
- (\*)  $Z_q - f_j = U_{qfj_1} - U_{qfj_2}$ ,  $j=1, \dots, M$ ,
- (\*)  $Z_q - f_M = U_{qfM_1} - U_{qfM_2}$ .

so as to render all of the constraints linear and amenable to computation using Linear Programming techniques.

25 18. The system according to Claim 15 to 17, further including:

- (f) a vertical shifter for iteratively shifting said model vertically in order to minimize total cost whilst taking into account the cross-section of each transportation route, so as to derive a set of control

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points having elevations that define vertical alignment of the transportation routes.

19. The system according to Claim 18, further including the step of adding control points and allowing a surface of the transportation route between adjacent control points to have a higher gradient.

20. The system according to Claim 18 or 19, wherein accuracy is improved by reducing a mutual separation between adjacent grid points.

21. The system according to any one of Claims 18 to 20, wherein accuracy is improved by providing a higher resolution digital terrain model.

22. The system according to any one of the Claims 15 to 21, wherein:  
at least one of the transportation routes includes one or more subdivision lots adjoining a boundary of the transportation route,

there is further stored in the memory data relating to respective sections and boundaries of said subdivision lots, and

the computer is responsive to the respective sections and boundaries of the subdivision lots so as to take into account earthworks required to conform an elevation of the transportation route to corresponding elevations of the subdivision lots.

23. The system according to any one of Claims 14 to 22, wherein the transportation route data includes data relating to at least one road.

24. The system according to any one of the preceding claims, wherein the transportation route data includes data relating to at least one rail track.

25. The system according to any one of Claims 14 to 24, wherein the transportation route data includes data relating to at least one pedestrian path.

26. The system according to any one of Claims 14 to 25 for processing data relating a plurality of transportation routes comprising an integrated project so as to optimize excavation costs for the project.

27. A storage medium storing therein a computer program for carrying out the method of any one of claims 1 to 13.

## PATENT COOPERATION TREATY

## PCT

## INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference <b>119715.1 DB</b>	<b>FOR FURTHER ACTION</b> see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, Item 5 below.	
International application No. <b>PCT/IL 99/00538</b>	International filing date (day/month/year) <b>13/10/1999</b>	(Earliest) Priority Date (day/month/year) <b>09/11/1998</b>
Applicant <b>MAKOR ISSUES AND RIGHTS LTD. et al.</b>		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.

☒ It is also accompanied by a copy of each prior art document cited in this report.

## 1. Basis of the report

- a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

☐ the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

- b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing:

☐ contained in the international application in written form.

☐ filed together with the international application in computer readable form.

☐ furnished subsequently to this Authority in written form.

☐ furnished subsequently to this Authority in computer readable form.

☐ the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

☐ the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. ☐ **Certain claims were found unsearchable** (See Box I).

3. ☐ **Unity of invention is lacking** (see Box II).

4. With regard to the **title**,

☒ the text is approved as submitted by the applicant.

☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

☒ the text is approved as submitted by the applicant.

☐ the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No.

☒ as suggested by the applicant.

☐ because the applicant failed to suggest a figure.

☐ because this figure better characterizes the invention.

4  
☐ None of the figures.

# INTERNATIONAL SEARCH REPORT

International Application No

PCT/IL 99/00538

**A. CLASSIFICATION OF SUBJECT MATTER**  
IPC 7 G06F17/60

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)  
IPC 7 G06F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 574 841 A (THOMPSON PHILIP G ET AL) 12 November 1996 (1996-11-12) abstract; claims 1-12 column 1, line 61 -column 8, line 10 ---	1,15
A	FLOOD I ET AL: "Modeling construction processes using artificial neural networks" AUTOMATION IN CONSTRUCTION,NL,ELSEVIER SCIENCE PUBLISHERS, AMSTERDAM, vol. 4, no. 4, 1 January 1996 (1996-01-01), pages 307-320, XP004047486 ISSN: 0926-5805 abstract page 313, column 2, line 8 -page 315, column 2, line 3; figure 6 --- -/-	1,15

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

\* Special categories of cited documents :

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- "&" document member of the same patent family

Date of the actual completion of the international search

21 March 2000

Date of mailing of the international search report

28/03/2000

Name and mailing address of the ISA

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# INTERNATIONAL SEARCH REPORT

International Application No

PCT/IL 99/00538

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>PAPAMICHAEL K ET AL: "Building Design Advisor: automated integration of multiple simulation tools"</p> <p>AUTOMATION IN CONSTRUCTION,NL,ELSEVIER SCIENCE PUBLISHERS, AMSTERDAM, vol. 6, no. 4, 1 August 1997 (1997-08-01), pages 341-352, XP004094137</p> <p>ISSN: 0926-5805</p> <p>abstract</p> <p>page 343, column 2, line 11 -page 351, column 2, line 4; figures 2-9</p> <p style="text-align: center;">---</p>	1,15
A	<p>SACKS R ET AL: "A project model for an automated building system: design and planning phases"</p> <p>AUTOMATION IN CONSTRUCTION,NL,ELSEVIER SCIENCE PUBLISHERS, AMSTERDAM, vol. 7, no. 1, 1 December 1997 (1997-12-01), pages 21-34, XP004103031</p> <p>ISSN: 0926-5805</p> <p>abstract</p> <p>page 31, column 2, line 11 -page 33, column 2, line 40</p> <p style="text-align: center;">-----</p>	1,15



# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/IL 99/00538

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5574841 A	12-11-1996	US 5633802 A	27-05-1997
		US 6012835 A	11-01-2000

From the INTERNATIONAL SEARCHING AUTHORITY

**PCT**

NOTIFICATION OF TRANSMITTAL OF  
THE INTERNATIONAL SEARCH REPORT  
OR THE DECLARATION

(PCT Rule 44.1)

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REINHOLD COHN & PARTNERS

Applicant's or agent's file reference <b>119715.1 DB</b>	Date of mailing (day/month/year) <b>28/03/2000</b>
International application No. <b>PCT/IL 99/00538</b>	International filing date (day/month/year) <b>13/10/1999</b>
Applicant <b>MAKOR ISSUES AND RIGHTS LTD. et al.</b>	

1. ☒ The applicant is hereby notified that the International Search Report has been established and is transmitted herewith.

**Filing of amendments and statement under Article 19:**

The applicant is entitled, if he so wishes, to amend the claims of the International Application (see Rule 46):

**When?** The time limit for filing such amendments is normally 2 months from the date of transmittal of the International Search Report; however, for more details, see the notes on the accompanying sheet.

**Where?** Directly to the International Bureau of WIPO  
34, chemin des Colombettes  
1211 Geneva 20, Switzerland  
Facsimile No.: (41-22) 740.14.35

For more detailed instructions, see the notes on the accompanying sheet.

2. ☐ The applicant is hereby notified that no International Search Report will be established and that the declaration under Article 17(2)(a) to that effect is transmitted herewith.

3. ☐ With regard to the protest against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

☐ the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.


☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Further action(s):** The applicant is reminded of the following:

Shortly after 18 months from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in Rules 90bis.1 and 90bis.3, respectively, before the completion of the technical preparations for international publication.

Within 19 months from the priority date, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase until 30 months from the priority date (in some Offices even later).

Within 20 months from the priority date, the applicant must perform the prescribed acts for entry into the national phase before all designated Offices which have not been elected in the demand or in a later election within 19 months from the priority date or could not be elected because they are not bound by Chapter II.

Name and mailing address of the International Searching Authority  European Patent Office, P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer <b>Lucia Van Pinxteren</b>
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## NOTES TO FORM PCT/ISA/220

These Notes are intended to give the basic instructions concerning the filing of amendments under article 19. The Notes are based on the requirements of the Patent Cooperation Treaty, the Regulations and the Administrative Instructions under that Treaty. In case of discrepancy between these Notes and those requirements, the latter are applicable. For more detailed information, see also the PCT Applicant's Guide, a publication of WIPO.

In these Notes, "Article", "Rule", and "Section" refer to the provisions of the PCT, the PCT Regulations and the PCT Administrative Instructions respectively.

### INSTRUCTIONS CONCERNING AMENDMENTS UNDER ARTICLE 19

The applicant has, after having received the international search report, one opportunity to amend the claims of the international application. It should however be emphasized that, since all parts of the international application (claims, description and drawings) may be amended during the international preliminary examination procedure, there is usually no need to file amendments of the claims under Article 19 except where, e.g. the applicant wants the latter to be published for the purposes of provisional protection or has another reason for amending the claims before international publication. Furthermore, it should be emphasized that provisional protection is available in some States only.

#### What parts of the International application may be amended?

Under Article 19, only the claims may be amended.

During the international phase, the claims may also be amended (or further amended) under Article 34 before the International Preliminary Examining Authority. The description and drawings may only be amended under Article 34 before the International Examining Authority.

Upon entry into the national phase, all parts of the international application may be amended under Article 28 or, where applicable, Article 41.

#### When?

Within 2 months from the date of transmittal of the international search report or 16 months from the priority date, whichever time limit expires later. It should be noted, however, that the amendments will be considered as having been received on time if they are received by the International Bureau after the expiration of the applicable time limit but before the completion of the technical preparations for international publication (Rule 46.1).

#### Where not to file the amendments?

The amendments may only be filed with the International Bureau and not with the receiving Office or the International Searching Authority (Rule 46.2).

Where a demand for international preliminary examination has been/is filed, see below.

#### How?

Either by cancelling one or more entire claims, by adding one or more new claims or by amending the text of one or more of the claims as filed.

A replacement sheet must be submitted for each sheet of the claims which, on account of an amendment or amendments, differs from the sheet originally filed.

All the claims appearing on a replacement sheet must be numbered in Arabic numerals. Where a claim is cancelled, no renumbering of the other claims is required. In all cases where claims are renumbered, they must be renumbered consecutively (Administrative Instructions, Section 205(b)).

The amendments must be made in the language in which the international application is to be published.

#### What documents must/may accompany the amendments?

##### Letter (Section 205(b)):

The amendments must be submitted with a letter.

The letter will not be published with the international application and the amended claims. It should not be confused with the "Statement under Article 19(1)" (see below, under "Statement under Article 19(1)").

The letter must be in English or French, at the choice of the applicant. However, if the language of the international application is English, the letter must be in English; if the language of the international application is French, the letter must be in French.

## NOTES TO FORM PCT/ISA/220 (continued)

The letter must indicate the differences between the claims as filed and the claims as amended. It must, in particular, indicate, in connection with each claim appearing in the international application (it being understood that identical indications concerning several claims may be grouped), whether

- (i) the claim is unchanged;
- (ii) the claim is cancelled;
- (iii) the claim is new;
- (iv) the claim replaces one or more claims as filed;
- (v) the claim is the result of the division of a claim as filed.

The following examples illustrate the manner in which amendments must be explained in the accompanying letter:

1. [Where originally there were 48 claims and after amendment of some claims there are 51]:  
"Claims 1 to 29, 31, 32, 34, 35, 37 to 48 replaced by amended claims bearing the same numbers; claims 30, 33 and 36 unchanged; new claims 49 to 51 added."
2. [Where originally there were 15 claims and after amendment of all claims there are 11]:  
"Claims 1 to 15 replaced by amended claims 1 to 11."
3. [Where originally there were 14 claims and the amendments consist in cancelling some claims and in adding new claims]:  
"Claims 1 to 6 and 14 unchanged; claims 7 to 13 cancelled; new claims 15, 16 and 17 added." or  
"Claims 7 to 13 cancelled; new claims 15, 16 and 17 added; all other claims unchanged."
4. [Where various kinds of amendments are made]:  
"Claims 1-10 unchanged; claims 11 to 13, 18 and 19 cancelled; claims 14, 15 and 16 replaced by amended claim 14; claim 17 subdivided into amended claims 15, 16 and 17; new claims 20 and 21 added."

### "Statement under article 19(1)" (Rule 46.4)

The amendments may be accompanied by a statement explaining the amendments and indicating any impact that such amendments might have on the description and the drawings (which cannot be amended under Article 19(1)).

The statement will be published with the international application and the amended claims.

**It must be in the language in which the international application is to be published.**

It must be brief, not exceeding 500 words if in English or if translated into English.

It should not be confused with and does not replace the letter indicating the differences between the claims as filed and as amended. It must be filed on a separate sheet and must be identified as such by a heading, preferably by using the words "Statement under Article 19(1)."

It may not contain any disparaging comments on the international search report or the relevance of citations contained in that report. Reference to citations, relevant to a given claim, contained in the international search report may be made only in connection with an amendment of that claim.

### Consequence if a demand for international preliminary examination has already been filed

If, at the time of filing any amendments under Article 19, a demand for international preliminary examination has already been submitted, the applicant must preferably, at the same time of filing the amendments with the International Bureau, also file a copy of such amendments with the International Preliminary Examining Authority (see Rule 62.2(a), first sentence).

### Consequence with regard to translation of the international application for entry into the national phase

The applicant's attention is drawn to the fact that, where upon entry into the national phase, a translation of the claims as amended under Article 19 may have to be furnished to the designated/elected Offices, instead of, or in addition to, the translation of the claims as filed.

For further details on the requirements of each designated/elected Office, see Volume II of the PCT Applicant's Guide.

Such equalization is an iterative process requiring repeated fine-tuning by the engineer. The iteration may be repeated numerous times before the road system satisfies all of the physical constraints and the cut and fill quantities are properly balanced. Conventionally, the design has been a trial and error affair according to the experience of the civil engineer. The vertical alignment is determined for one road at a time and not for the entire road system. Earthworks of subdivision lots which border transportation routes have also not conventionally been taken into account, nor has the economical factor been properly considered.

## 10 SUMMARY OF THE INVENTION

A principal the object of the invention is thus to develop a method of road design that results in lower construction cost.

A further object of the invention is to facilitate comparison of different layouts and different unit prices so as to obtain better cost-effectiveness during the preliminary planning stage.

According to a broad aspect of the invention there is provided a computer-implemented method for designing transportation routes, the method comprising the steps of:

- (a) supplying design criteria to be met in respect of at least one of said transportation routes,
- (b) obtaining route profile data showing land heights at sampled points along each of said at least one transportation route,
- (c) supplying per-unit cost estimates in respect of land-cut and land-fill operations, and
- (d) computing a height profile of said at least one transportation route which meets said design criteria and for which said land-cut and land-fill operations are adjusted to give a minimum cost.

Such a method establishes a direct relationship between prevailing economic conditions and the status of the transportation system as a technical

$$\sum_{j=1}^{j=K} \sum_{i=1}^{i=N_j} (D_{(i-1),j} + D_{ij}) \cdot (Z_{ij} + 10,000) - \sum_{j=1}^{j=K} \sum_{i=1}^{i=N_j} (D_{(i-1),j} + D_{ij}) \cdot 10,000 < 0 \text{ or } > 0$$

### Constraints:

(a) Elevations of intersection points of different roads having respective indices j1 and j2 must be same, i.e.:

$$Z_{1j1} + H_{1j1} - Z_{1j2} - H_{1j2} = 0,$$

Where:

1<sup>st</sup> point of j1<sup>th</sup> road coincides with 1<sup>st</sup> point of j2<sup>th</sup> road;

Z<sub>1j1</sub> and Z<sub>1j2</sub> are relative elevations at these points;

H<sub>1j1</sub> and H<sub>1j2</sub> are existing elevations at these points.

10 (b) The absolute value of the gradient between adjacent control points (i, j) having respective elevations H<sub>ij</sub> and H<sub>(i+1),j</sub> cannot exceed a predetermined allowable maximum value, Gmax:

$$|Z_{ij} + H_{ij} - Z_{(i+1),j} - H_{(i+1),j}| / D_{ij} < Gmax,$$

for j = 1, ..., K; i = 1, ..., N<sub>j</sub>.

15 (c) Elevation at each CP should belong to maximal possible allowable interval:

$$Z_{i_0, j_0} < 10,000 + \max \left\{ 0, 0.5 \cdot \left\{ \max_{i=1}^{i=K} \max_{j=1}^{j=N_j} (H_{i,j} - H_{i_0, j_0} - D_{i_0, j_0, i, j} \cdot Gmax) \right\} \right\}$$

Equation (12)

and

$$Z_{i_0, j_0} > 10,000 - \min \left\{ 0, 0.5 \cdot \left\{ \min_{i=1}^{i=K} \min_{j=1}^{j=N_j} (H_{i,j} - H_{i_0, j_0} + D_{i_0, j_0, i, j} \cdot Gmax) \right\} \right\}$$

Equation (13)

**CLAIMS:**

1. A computer-implemented method for designing transportation routes, the method comprising the steps of:
  - (a) supplying design criteria to be met in respect of at least one of said transportation routes,
  - (b) obtaining route profile data showing land heights at sampled points along each of said at least one transportation route,
  - (c) supplying per-unit cost estimates in respect of land-cut and land-fill operations, and
  - (d) computing a height profile of said at least one transportation route which meets said design criteria and for which said land-cut and land-fill operations are adjusted to give a minimum cost.
2. The method according to Claim 1, wherein step (d) includes:
  - i) representing a surface of the at least one transportation route as a 3-dimensional model having grid points and boundary grid points,
  - ii) defining control points such that a gradient of the road surface is constant between adjacent control points, and
  - iii) calculating a respective elevation of each point on the road surface between adjacent control points as well as a respective elevation of each control point using linear or non-linear programming.
3. The method according to Claim 1, wherein step (d) includes:
  - i) representing a surface of the at least one transportation route as a 3-dimensional model having grid points and boundary grid points,
  - ii) defining control points such that a gradient of the road surface is constant between adjacent control points, and
  - iii) calculating a respective elevation of each point on the road surface between adjacent control points as well as a respective

elevation of each control point using linear or non-linear programming.

4. The method according to Claim 1, wherein step (d) includes:

- i) representing a surface of the at least one transportation route as a 3-dimensional model having grid points and boundary grid points,
- ii) defining control points such that a gradient of the road surface is constant between adjacent control points, and
- iii) calculating a respective elevation of each point on the road surface between adjacent control points as well as a respective elevation of each control point using linear or non-linear programming.

5. The method according to any one of Claims 2 to 4, wherein the route profile data includes soil composition and per unit excavation cost for each different level having a discrete soil composition.

6. The method according to Claim 2 or 5, further including:

- (e) iteratively shifting said model vertically in order to minimize total cost whilst taking into account the cross-section of each transportation route, so as to derive a set of control points having elevations that define vertical alignment of the transportation routes.

7. The method according to Claim 6, further including the step of adding control points and allowing a surface of the transportation route between adjacent control points to have a higher gradient.

8. The method according to Claim 6 or 7, wherein accuracy is improved by reducing a mutual separation between adjacent grid points.

9. The method according to any one of Claims 6 to 8, wherein accuracy is improved by providing a higher resolution digital terrain model.

10. The method according to any one of the Claims 2 to 9, wherein at least one of the transportation routes includes one or more subdivision lots adjoining a boundary of the transportation route and in step (d)(i) there are



added to the model respective sections and boundaries of said subdivision lots so as to take into account earthworks required to conform an elevation of the transportation route to corresponding elevations of the subdivision lots.

11. The method according to any one of the preceding claims, wherein  
5 the transportation routes include at least one road.

12. The method according to any one of the preceding claims, wherein the transportation routes include at least one rail track.

13. The method according to any one of the preceding claims, wherein the transportation routes include at least one pedestrian path.

10 14. The method according to any one of the preceding claims applied to a plurality of transportation routes comprising an integrated project so as to optimize excavation costs for the project.

15 15. A computer-implemented system for designing transportation routes, said system comprising a computer coupled to a memory and a data output device,

(a) there being stored in the memory transportation route data including:

- i) design criteria to be met in respect of at least one of said transportation routes,
- 20 ii) route profile data showing land heights at sampled points along each of said at least one transportation route, and
- iii) per-unit cost estimates in respect of land-cut and land-fill operations; and

25 (b) the computer being responsive to the design criteria, the route profile data and the per-unit cost estimates for computing a height profile of said at least one transportation route which meets said design criteria and for which said land-cut and land-fill operations are adjusted to give a minimum cost.

30 16. The system according to Claim 15, wherein the computer is programmed to:

- i) represent a surface of the at least one transportation route as a 3-dimensional model having grid points and boundary grid points,
- ii) define control points such that a gradient of the road surface is constant between adjacent control points, and
- 5      iii) calculate a respective elevation of each point on the road surface between adjacent control points as well as a respective elevation of each control point using linear or non-linear programming.

17. The system according to Claim 15, wherein the computer is programmed to:

- 10      i) representing a surface of the at least one transportation route as a 3-dimensional model having grid points and boundary grid points,
- ii) defining control points such that a gradient of the road surface is constant between adjacent control points, and
- 15      iii) calculating a respective elevation of each point on the road surface between adjacent control points as well as a respective elevation of each control point using linear or non-linear programming.

18. The system according to Claim 15, wherein the computer is programmed to:

- 20      i) representing a surface of the at least one transportation route as a 3-dimensional model having grid points and boundary grid points,
- ii) defining control points such that a gradient of the road surface is constant between adjacent control points, and
- 25      iii) calculating a respective elevation of each point on the road surface between adjacent control points as well as a respective elevation of each control point using linear or non-linear programming.

19. The system according to any one of Claims 16 to 18, wherein the route profile data includes soil composition and per unit excavation cost for  
30 each different level having a discrete soil composition.

20. The system according to Claim 16 to 19, further including:
- (f) a vertical shifter for iteratively shifting said model vertically in order to minimize total cost whilst taking into account the cross-section of each transportation route, so as to derive a set of control points having elevations that define vertical alignment of the transportation routes.
21. The system according to Claim 20, further including the step of adding control points and allowing a surface of the transportation route between adjacent control points to have a higher gradient.
22. The system according to Claim 20 or 21, wherein accuracy is improved by reducing a mutual separation between adjacent grid points.
23. The system according to any one of Claims 20 to 22, wherein accuracy is improved by providing a higher resolution digital terrain model.
24. The system according to any one of the Claims 16 to 23, wherein:
- at least one of the transportation routes includes one or more subdivision lots adjoining a boundary of the transportation route,
- there is further stored in the memory data relating to respective sections and boundaries of said subdivision lots, and
- the computer is responsive to the respective sections and boundaries of the subdivision lots so as to take into account earthworks required to conform an elevation of the transportation route to corresponding elevations of the subdivision lots.
25. The system according to any one of Claims 15 to 24, wherein the transportation route data includes data relating to at least one road.
26. The system according to any one of the preceding claims, wherein the transportation route data includes data relating to at least one rail track.
27. The system according to any one of Claims 15 to 26, wherein the transportation route data includes data relating to at least one pedestrian path.

28. The system according to any one of Claims 15 to 27 for processing data relating a plurality of transportation routes comprising an integrated project so as optimize excavation costs for the project.

29. A storage medium storing therein a computer program for carrying  
5 out the method of any one of claims 1 to 14.

From the:  
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:

REINHOLD COHN AND PARTNERS  
P.O. Box 4060  
61040 Tel-Aviv  
ISRAEL

**RECEIVED**

23-08-2000

REINHOLD COHN & PARTNERS

**PCT**

**WRITTEN OPINION**

(PCT Rule 66)

Date of mailing  
(day/month/year)

23.11.2000 okv

23.08.2000

Applicant's or agent's file reference

119715.1 DB

**REPLY DUE**

**within 3 month(s)**  
from the above date of mailing

International application No.

PCT/IL99/00538

International filing date (day/month/year)

13/10/1999

Priority date (day/month/year)

09/11/1998

International Patent Classification (IPC) or both national classification and IPC

G06F17/60

Applicant

MAKOR ISSUES AND RIGHTS LTD. et al.

1. This written opinion is the **first** drawn up by this International Preliminary Examining Authority.

2. This opinion contains indications relating to the following items:

- I ☒ Basis of the opinion
- II ☐ Priority
- III ☒ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- IV ☐ Lack of unity of invention
- V ☐ Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- VI ☐ Certain document cited
- VII ☒ Certain defects in the international application
- VIII ☒ Certain observations on the international application

3. The applicant is hereby **invited to reply** to this opinion.

**When?** See the time limit indicated above. The applicant may, before the expiration of that time limit, request this Authority to grant an extension, see Rule 66.2(d).

**How?** By submitting a written reply, accompanied, where appropriate, by amendments, according to Rule 66.3. For the form and the language of the amendments, see Rules 66.8 and 66.9.

**Also:** For an additional opportunity to submit amendments, see Rule 66.4.  
For the examiner's obligation to consider amendments and/or arguments, see Rule 66.4 bis.  
For an informal communication with the examiner, see Rule 66.6.

**If no reply is filed,** the international preliminary examination report will be established on the basis of this opinion.

4. The final date by which the international preliminary examination report must be established according to Rule 69.2 is: 09/03/2001.

Name and mailing address of the international preliminary examining authority:



European Patent Office  
D-80298 Munich  
Tel. +49 89 2399 - 0 Tx: 523656 epmu d  
Fax: +49 89 2399 - 4465

Authorized officer / Examiner

Krischer, S

Formalities officer (incl. extension of time limits)

Schall, H

Telephone No. +49 89 2399 2647



**I. Basis of the opinion**

1. This opinion has been drawn on the basis of (*substitute sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this opinion as "originally filed".*):

**Description, pages:**

1-21 as originally filed

**Claims, No.:**

1-29 as originally filed

**Drawings, sheets:**

1-5 as originally filed

2. The amendments have resulted in the cancellation of:

- ☐ the description, pages:  
☐ the claims, Nos.:  
☐ the drawings, sheets:

3. This opinion has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

4. Additional observations, if necessary:

**III. Non-establishment of opinion with regard to novelty, inventive step and industrial applicability**

The questions whether the claimed invention appears to be novel, to involve an inventive step (to be non-obvious), or to be industrially applicable have not been and will not be examined in respect of:

- ☒ the entire international application.  
☐ claims Nos. ,

because:

- ☐ the said international application, or the said claims Nos. relate to the following subject matter which does not require an international preliminary examination (*specify*):

- ☒ the description, claims or drawings (*indicate particular elements below*) or said claims Nos. 1-29 are so unclear that no meaningful opinion could be formed (*specify*):

**see separate sheet**

- ☒ the claims, or said claims Nos. 1-29 are so inadequately supported by the description that no meaningful opinion could be formed.

- ☐ no international search report has been established for the said claims Nos. .

**VII. Certain defects in the international application**

The following defects in the form or contents of the international application have been noted:

**see separate sheet**

**VIII. Certain observations on the international application**

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

**see separate sheet**

**Re Item III**

**Non-establishment of opinion with regard to novelty, inventive step and industrial applicability for claims 1-5**

- 1 For independent claims 1 and 15, the reasons are set out in section VIII.
- 2 Since the dependent claims refer to invalid independent claims, no opinion can be established either.

**Re Item VII**

**Certain defects in the international application**

- 3 Reference is made to the following document:  
  
D1 Allen, L. G.; Poidevin, M. G. "Cost Effective Design - The Use of Computer Aided Drafting In: Route Selection, Earthworks Optimisation and Rail Track Engineering", Conference on Railway Engineering, Perth/Australia September 1987; XP-000917757
- 4 Independent claims 1 and 15 are not in the **two-part form** in accordance with Rule 6.3(b) PCT, which in the present case would be appropriate, with those features known in combination from the prior art (document D1) being placed in the preamble (Rule 6.3(b)(i) PCT) and with the remaining features being included in the characterising part (Rule 6.3(b)(ii) PCT).
- 5 The features of all claims are not provided with **reference signs** placed in parentheses (Rule 6.2(b) PCT).
- 6 Contrary to the requirements of Rule 5.1(a)(ii) PCT, the **relevant background art** disclosed in the document D1 is not mentioned in the description, nor is this document identified therein.

**Re Item VIII**



**Certain observations on the international application**

7 The application does not meet the requirements of Article 6 PCT, because independent claims 1 and 15 are **not clear**.

8 **Clarity of claim 1:**

8.1 The expression "**design criteria**" (line 4) is unclear since it is so **broad** that it covers **any** property which may arise during the design phase; e.g., also informal properties which cannot be handled by a computer-implemented method.

Therefore, the form (e.g. the data structure) and the appropriate kind of "design criteria" should have been stated.

8.2 It is not clear what the expression "**route profile**" (line 6) means in this context. Is this profile **two- or three-dimensional**, does it contain the **height values**? Does it define the **final route** or the **landscape** before constructing the route?

8.3 The term "**per-unit cost estimates**" (line 8) is not clear. Does the term "unit" relate to a **physical dimension** (which one? Mass? Volume?) or to a working unit (e.g. the land-fill and land-cut operations of the route between points A and B)?

8.4 The *main* clarity problem is that the claim attempts to define the subject-matter in terms of the *result to be achieved* which merely amounts to a statement of the underlying problem: the step (d) of "*computing a height profile*" (line 10) is the *kernel* of the claimed "computer-implemented method for designing transportation routes" (line 2) since it is the only design step in the method ((a), (b) and (c) are input steps). The claim does not define *how* this computation step should be executed. The technical features necessary for achieving this result are missing. No *algorithm* for this computation is given. Therefore, it is unclear how perform the main step of the method. It is especially unclear how the additional conditions of "meeting said design criteria" (line 11) and of "giving a minimum cost" should be reached.

9 **Clarity of independent claim 15:**

9.1 The clarity objections of method claim 1 apply accordingly to system claim 15.

10 **Clarity of dependent claims:**

10.1 The following expressions are unclear:

- **"boundary grid points"** (step i) of claims 2, 16): this is not a well-defined technical term in this field. The essential technical features of "boundary grid points" are missing.
- **"defining control points"** (step ii) of claims 2, 16): Control points are "3D points of the proposed centerlines of the road system" according to the description, page 4, line 27. Are the control points entered by the user? Are they computed by the method? How? Why should their elevation be computed a second time in step iii), since their elevation is already determined (the control points are "3D")?
- **"calculating a ... elevation ... using linear or nonlinear programming"** (step iii) of claims 2, 16): This is again a definition of the subject-matter in terms of the **result to be achieved** which merely amounts to a statement of the underlying problem as in claim 1. The following **questions** arise: How are the elevation values computed? There are so many linear and nonlinear programming solution techniques: Which one can be used? Which one cannot be used? How are they used? How is the optimization problem formulated as a nonlinear and as a linear programming task? What are the variables to minimize? What is the objective function? What are the constraints? How is the problem of local minima treated?
- **"allowing a surface ... between adjacent control points to have a higher gradient"** (claims 7, 21): This is a **contradiction** to the definition of control points in claim 2, ii) as marking regions of a constant gradient.
- **"take into account earthworks"** (claim 10, line 2; claim 24): What measurable property of these earthworks should influence which computation by which formula or algorithm, and how?

10.2 **Claims 3 and 4 are literally identical** with claim 2.

10.3 Claims 17 and 18 are **literally identical** with claim 16 except the "ing"-form.

11 **Clarity of the description:**

11.1 The passage on page 21, lines 15-18 contradicts the normal interpretation that steps of a method are executed in the order given by the claim.

Such an **important feature about the structure of the claims** should have been **explicitly included in each claim**.

11.2 The formula in Equation (13) (page 15, last line) is superposed with the text "Equation (11)" and therefore hard to read.

12 **Sufficient disclosure:**

12.1 **The description does not satisfy Article 5 PCT, i.e. that the invention is *not disclosed in sufficient detail for a person skilled in the art to reproduce it.***

12.2 The description does **not disclose** how to perform **the most important step** of the method and system for designing transportation routes, which is the step of **computing a height profile** such that (unspecified) design criteria are met and that **land-cut and land-fill costs** are **minimized**.

It is **impossible** for a skilled person to use the claimed method, to construct the claimed system, or to program the claimed computer program without being taught **how the core** of the method/system/program **works**.

The description only gives **three vague formulations of the optimization problem** as two nonlinear and one linear programming tasks, **without disclosing a solution technique** for any of these problem formulations. The **deficiencies** of the problem formulations are the following:

- first nonlinear programming problem formulation, called "grid optimization" (pages 4-12): It is well-known that researchers are obliged to identify **special cases** (e.g. **linearly constrained optimization, or quadratic programming**) to study solution techniques because nonlinear programming is such a **difficult field**. The **description fails** in stating to which special

case its problem formulation belongs to, whether there are standard solution techniques for that special case, which of them are adapted for the problem, and how such a technique should be used in this case.

- "linear" programming problem formulation, called "centerline optimization" (pages 12-16): Although the description states that this problem formulation is linear, it seems that it is **not linear** since the **constraints are not linear**. For example the constraints b) and c) (page 15) contain the nonlinear functions "abs", "max" and "min" which cannot be represented by matrices. Furthermore, in the case it was a linear programming problem formulation, the description would not teach **which one of the various solution techniques would be adapted** to the problem (e.g. which one of the families of **simplex methods** or of **interior-point methods**).
- second nonlinear programming problem formulation "centerline optimization" (pages 16-18): The same objections as for the first nonlinear programming problem formulation hold.

12.3 Even if the applicant would succeed in teaching which **solution technique for nonlinear programming** can be used in this case, **without departing from the disclosure of the application as originally filed**, the mere application of such a technique or of a commercially available computer-program implementing that technique would **not involve an inventive step**, since this would only be the **intended use** of such a technique or program.

12.4 The following **questions** arise when a skilled person tries to implement the invention:

- How are the **various optimization steps** in Figure 1 executed (boxes "optimization process", "optimization of transportation", "optimal points of intersection", "optimal vertical alignment of roads and lots", "optimal cross sections", "optimal quantity output", "minimum cost output", "optimal transportation output")? What is the relation between these optimization steps and the three optimization problem formulations on pages 4-18?
- How do the earthworks for subdivision lots (page 19) influence the optimization algorithms? What are the measurable parameters of these lots that are necessary for the computation?

- As to Equation (1) (page 6): What is the meaning of " $N$ "? Which points  $Q$  are used? Grid points, boundary grid points, control points, any other points?
- Where do the "proposed elevations" (page 5, line 23; page 6, line 4) come from? Are they input by the user? Are they computed by the method? How?

**12.5 In order to overcome the above objections, *reasoned arguments with evidence*, should be submitted that the person skilled in the art could *resolve all these questions, without inventiveness* on his part, from the prior art or the *current* description.**